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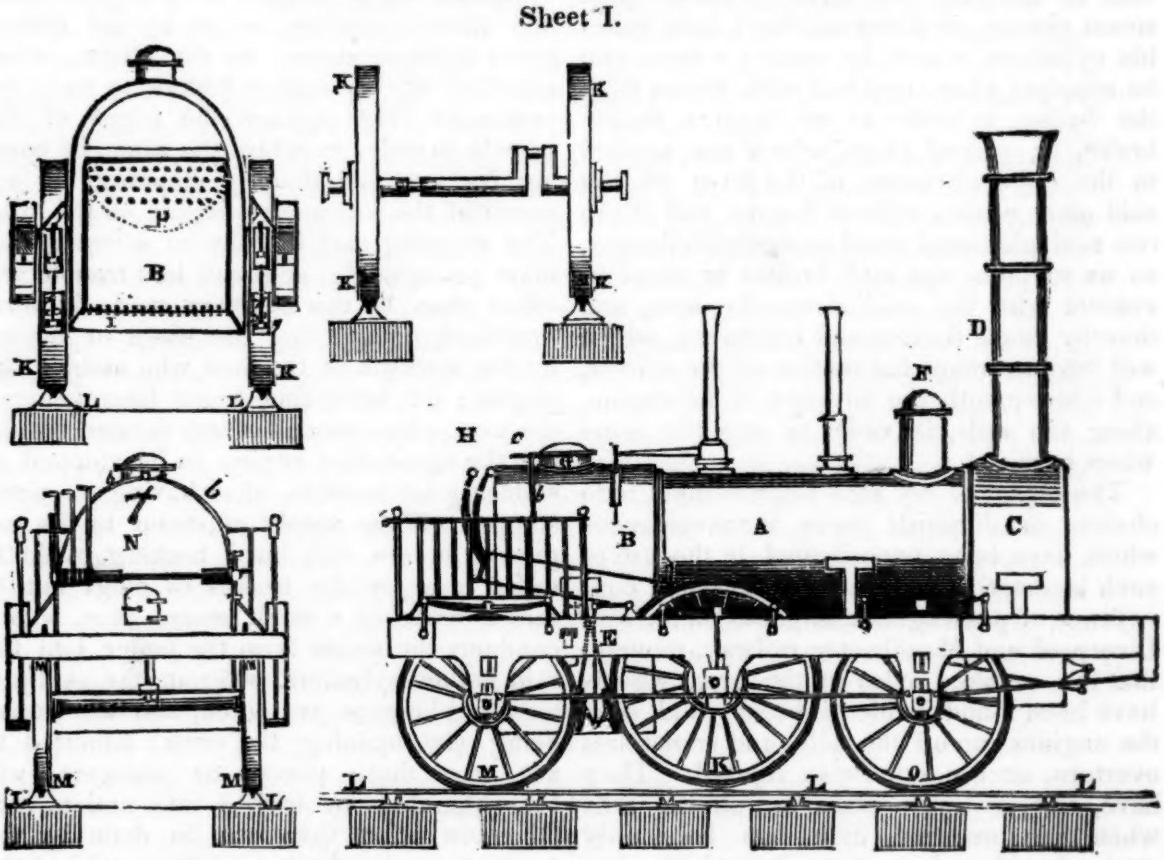
"Theoretical and practical men will most effectually promote their mutual interests, not by affecting to despise each other, but by blending their efforts; and an essential service will be done to mechanical science, by endeavoring to make all the scattered rays of light they have separately thrown upon this region of human knowledge converge to one point."—DR. OLINTHUS GREGORY.

STEPHENSON'S IMPROVED LOCOMOTIVE STEAM ENGINE.

Sheet I.



References.—A, the boiler; B, fire-box; C, smoke-box; D, smoke-pipe; E, suspension pin; F, steam head; G, man hole; H, working gear; J, fire grate; K, main impelling wheels; L, M, extra small wheels; N, throttle valve; P, tubes.

[From the Repertory of Patent Inventions.]

Specification of the Patent granted to ROBERT STEPHENSON, *of Newcastle-upon-Tyne, in the County of Northumberland, Engineer, for a certain Improvement in the Locomotive Steam Engines now in Use for the Quick Conveyance of Passengers and Goods upon Edge Railways.*—Sealed October 7, 1833.

My improvement in the locomotive steam engines now in use, for the quick conveyance of passengers and goods upon edge railways, is applicable to that kind of locomotive engines which are used in the Liverpool and Manchester railway (the first of which engines was called by the name of the Planet), having the two main wheels, which are impelled by the engine, fixed on a double cranked axis, and turned round by the force of the pistons of the steam cylinders, in order to advance the locomotive engine along the edge rails, whereon the said main wheels bear. And my said improvement consists in making the said main wheels of the locomotive engine (which are fixed as aforesaid) on the ends of the cranked axis,

and impelled by the force of the pistons, with plain tires to run upon the edge rails, without any projecting flanges on those tires, and applying two additional small wheels with flanges on their tires, beneath the hinder end or part of the engine, in order to cause that end of the engine, by means of those flanges, to keep straight upon the rails, as it runs along thereon, and also to bear up part of the weight of the furnace end of the boiler, in the same manner as the present two small wheels (by means of their flanges) keep that end of the engine straight ou the rails, and bear part of the weight at the chimney end of the boiler, where the steam cylinders are situated. And also consists in applying the force of small extra steam pistons, or plungers, fitted into suitable cylinders, which, by turning a cock, can be supplied when required with steam from the boiler, in order to act upon a double brake, or pair of clogs, which are applied to the circumferences of the tires of the said main wheels without flanges, and of the two said additional small wheels with flanges, so as to press the said brakes or clogs in contact with the said circumferences, and thereby cause friction and resistance, which will tend to retard the motion of the wheels, and consequently the advance of the engine, along the rails, in order to stop the same when required.

The object of my said improvement is to obviate or diminish some inconveniences which have been experienced in the use of such locomotive engines, for the quick conveyance of passengers and goods on the said Liverpool and Manchester railway, namely, that the cranked axles of the great wheels have been found liable to break, and then the engines run off the rails, and sometimes overturn, or are otherwise injured. They have, also, in some cases run off the rails when the cranked axle has been only strained, without being actually broken; also, it is found difficult to hold on with the clogs or brakes to the wheels of such locomotive engines, according to the manner whereby the brakes are usually applied by hand, with sufficient force and steadiness to retard the engines from advancing along the rails, as much as is desirable, in order to arrest their motion as suddenly as possible when they have been travelling rapidly, and particularly in the event of arriving at a broken or deranged part of the railroad, or on any other occurrence which may occasion danger of collision with obstacles or other carriages, if the motion were not stopped with promptitude; and also the boilers of those engines have burned out very rapidly, in their internal tubes, so as to have occasioned great expense and loss of work in repairing them.

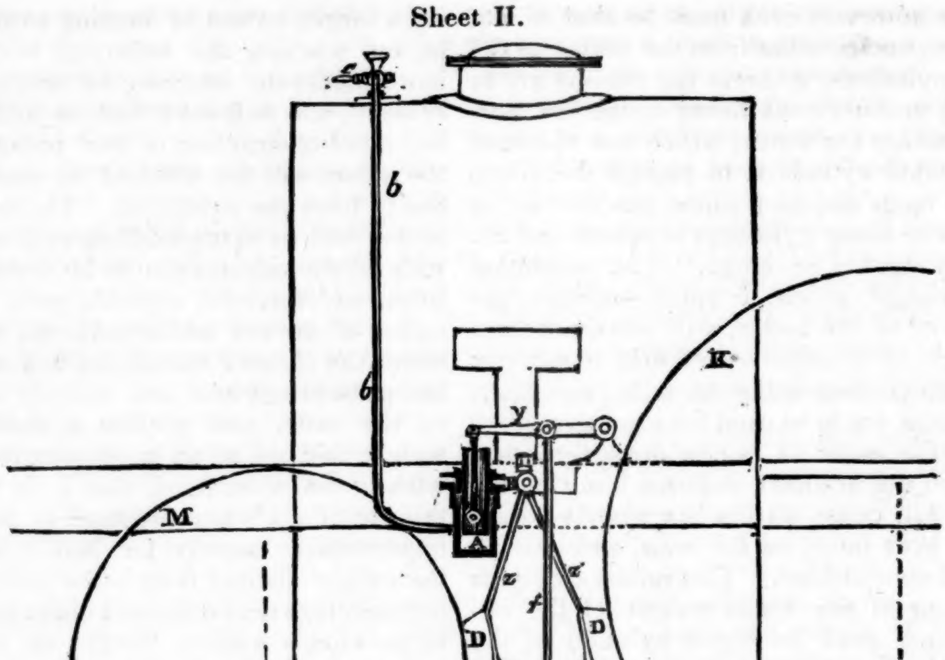
My said improvement in such kind of locomotive engines will tend to obviate or diminish the said inconveniences, for by using plain tires, without flanges, for the main impelled wheels (and which has never been done before in such engines on edge railways), the cranked axles of those wheels will not be subjected to any strain endways, in the direction of its length, when the engine enters into sidings, turnings, and crossings of the rails, or passes along curvatures in the line. * * * * *

* * And by applying the pressure of steam from the boiler to act within hollow cylinders, upon pistons or plungers fitted into those cylinders, so as by the motion given to those pistons by the steam, when admitted into the said cylinders, to force the brakes or clogs against the edges of the wheels, in order to retard the same, by causing friction, and thereby stopping the advance of the locomotive engine on the rails. The stopping may thereby be effected with more promptitude, and with less trouble and effort than by the ordinary mode hitherto practised, of applying the clogs or brakes by the strength of the man who attends the engine; for, according to my improvement, the man, when warned of any danger, requiring the locomotive engine to be stopped as suddenly as possible, after having as usual stopped off the supply of steam to the engine cylinders, will have nothing to do in order to apply the brakes or clogs but to turn a cock in a small steam pipe, which conducts the steam from the boiler into the said hollow cylinders, wherein the said pistons or plungers are fitted, and the steam being (by opening the cock) admitted to act upon those pistons or plungers, will bring the clogs or brakes into action, with far more effect than can be done by the common mode of pressing them against the wheels by handle levers, actuated by man's strength; and also according to my improvement, the man, after having opened the said cock, and so brought the brakes or clogs into action by the force of steam, will have his hands at liberty to do any other duty that may be required of him whilst the engine is stopping. And note—the same effect may be produced by admitting water from the boiler, by a pipe and cock as aforesaid, into the said hollow cylinders, in lieu of steam, because the pressure of the water will produce the same effect on the pistons or plungers, and clogs or brakes, as that of the steam. And in order to release the said clogs or brakes, and take them out of ac-

tion, the aforesaid cock must be shut, to cut off the communication from the boiler to the hollow cylinders, wherein the pistons are to act, and another cock being opened to permit the steam (or water) which has operated in the hollow cylinders, to escape therefrom into the open air, and allow the pistons or plungers in those cylinders to return and release the brakes or clogs. The additional small wheels which I apply beneath the hinder end of the boiler, will sustain the extra weight of a larger boiler than heretofore used, without distressing the rails; and bearing springs are to be used for the extra small wheels, the same as is now done for other wheels in the ordinary engines, and the said springs will cause all the six wheels to apply and bear fairly on the rails, and ease all jolts and concussions. The relative weights or portions of the whole weight of the engine, which shall be borne by each of the six wheels, being regulated by the strength and setting of their respective bearing springs. The main wheels, which are to be impelled by the power of the engine, being in all cases left loaded with as much of the weight of the engine as will cause a sufficient adhesion of those wheels to the rails to avoid slipping thereon. When by virtue of my improvement a larger boiler is used, containing more heating surface than heretofore, a less intense excitement of the combustion will be required in order to produce the necessary quantity of steam for the supply of the engine, and that diminution of the intensity of the combustion will be advantageous to the performance of the engine for another reason, as well as by avoiding the heretofore rapid burning out of the metal of the boiler, because the jet of waste steam (which is thrown into the chimney to produce a rapid draft therein, and a consequently intense combustion of the fuel,) may be greatly diminished in its velocity, and thereby the waste steam will be allowed to escape more freely from the cylinders than heretofore, when a very sharp and sudden jet of the waste steam up the chimney is found absolutely necessary to excite that intense violence of combustion which can alone enable the present boilers to yield the requisite supply of steam, but that very sudden jet can only be obtained by throttling the eduction passage, and thereby impeding the free discharge of the steam from the working cylinders, so as to impair the force of the pistons; and at the same time, the excessive combustion which is excited (by so impairing the force of the pistons) also destroys the metal of the boiler in a short time. Increasing the magnitude of the boiler, giving a larger extent of heating surface thereto, and working the enlarged boiler with a more moderate intensity of fire, is the true remedy, and will save fuel as well as avoid the rapid destruction of the boiler, because the steam will be allowed to escape more freely from the cylinders. The adoption of larger boilers in the said locomotive engines, with all the advantages to be derived therefrom, as aforesaid, depends upon the application of the two additional small wheels beneath the furnace end of the boiler, because the present engines are already too heavy on the rails, and require a diminution of weight instead of an augmentation. But I wish to be understood, that I do not claim the use of six wheels instead of four, as an improvement merely for better supporting the weight distinct from other circumstances hereinbefore set forth, but I claim the using of large wheels without flanges on their tires, which wheels are to be fixed on the cranked axle to serve for the impelled wheels of locomotive engines, which are to travel on edge railways, and in conjunction therewith, (but not without that conjunction,) the application of a pair of extra small wheels, with flanges on their tires, beneath the hinder end of the boiler, with interposed bearing springs, like those of the other wheels; that application of extra small wheels with flanges, conjointly with the said using of large impelled wheels without flanges, being for the purpose of keeping the engine straight on the rails when it runs forward, as well as for bearing up part of the weight. And also I claim, as part of my said improvement, the application (as hereinbefore described) of the pressure of the steam or water from the boiler, to act when required in hollow cylinders on pistons or plungers, which are connected with the clogs or brakes for the wheels, so as to bring the said brakes or clogs into action by the pressure of the steam instead of by the strength of men, as heretofore done. Note—I make no claim to the use of six wheels in locomotive engines to travel on edge railways, if the impelled wheels have flanges, but only when the said impelled wheels have no flanges; and for the more complete explanation of my said invention, I have hereunto annexed three sheets of drawings, (No. 3 is omitted in the engravings,) representing two locomotive engines for the quick conveyance of passengers and goods upon edge railways, when constructed according to my said improvement.

Sheet I. contains a side elevation, end elevation, and end section of such an engine. K are the main impelled wheels on the

Sheet II.



i, moveable plunger

cranked axle, without any projecting flanges on the tires, which run on the edge rails. L, M, are the extra small wheels with flanges, applied beneath the hinder or furnace end of the boiler; and O are the ordinary small wheels with flanges beneath the chimney end of the boiler, where the working steam cylinders are situated. The small wheels, O and M, with flanges, keep the engine straight on the rails as it runs forwards thereon; and the large impelled wheels, K, have only to advance the engine forwards, and to bear a due portion of its weight, without having any thing to do with keeping the engine on the rails, having no flanges which can hold laterally on the rails; wherefore the cranked axle of the wheels, K, is liberated from all stress by any lateral action of the great wheels K against the edges of the rails; and the small wheels, O M, with flanges, (which wheels have straight axles,) sustain all the stress of that lateral action.

Sheet II. contains a separate drawing of the brake or clog, which is also shown in its place in sheet I. A is the hollow cylinder into which a plunger is fitted, to act by a lever, *y*, and an upright rod, *f*, upon the two clogs or brakes, D, D, which are suspended by pendulous links, *z*, from a centre pin or bolt, E, fixed to the frame. The clogs or brakes, D D, are caused to apply to the circumferences of the tires of the wheels, K, and M, by means of links, *g*, *g*, which are interposed between the two clogs or brakes, D, D, and which links, when put down into an angle, as shown in the figure, leave the brakes or clogs, D, D, free of the wheels, K, and M; but when by opening the cock, *c*, the stream from the boiler is admitted through the pipe, *b*, *b*, into the hollow cylinder, A, it raises up the plunger therein, and that by its lever, *y*, and rod, *f*, draws up the links, *g*, *g*, towards a straight line, and then they force the two clogs or brakes, D, D, apart from each other against the wheels, K, and M, with an increased force beyond that which the plunger exerts; that increase of force being in consequence of the leverage at *y*, and the oblique direction of the links, *g*, *g*. When the handle of the cock, *c*, is turned the other way, it allows the steam to issue through an upright spout, and escape from the cylinders into the open air.

Enrolled December 3, 1833.

Method of Building Chimneys that will not Smoke.—Contract the space immediately over the fire, so you may be sure of the air being well heated *there;* this will ensure a current upwards. All chimneys should be carefully built, and every joint well filled with mortar, so as to prevent communication in case of fire.—[Dr. Thomas Cooper.]

A Compendium of Civil Architecture, arranged in Questions and Answers, with Notes, embracing History, the Classics, and the Early Arts, &c. By Robert Brindley, Architect, Surveyor, and Engineer. [Continued from page 278.]

SURVEYOR'S MEMORANDA.

I.—*Digger.*

27 Cube feet, one cube yard or single load.
54 Cube feet, two cube yards or double load.

II.—*Well Digger.*

ft.	in.			
3	0	Diameter in the clear, between brick-work, will contain, in each foot in depth,	43	galls. water.
3	6	in clear	59	do.
4	0	do.	77	do.
4	6	do.	98	do.
5	0	do.	120	do.
5	6	do.	146	do.
6	0	do.	173	do.
6	6	do.	203	do.
7	0	do.	235	do.
7	6	do.	270	do.
8	0	do.	308	do.
8	6	do.	348	do.
9	0	do.	390	do.
9	6	do.	435	do.
10	0	do.	480	do.

III.—*Bricklayer.*

272 Feet superficial, 1 rod of brick-work, at 1½ brick or 13½ inches thick, which is considered the standard thickness, and to which all brick-work is reduced.

306 Cube feet, one rod of reduced brick-work, being the cube quantity produced by multiplying 272 feet by 13½ inches (or 1½ brick, the standard thickness of all brick-work.)

4500 Bricks (allowing for waste) will build one rod of reduced brick-work.

17 Bricks to each reduced foot of brick-work.

8 Bricks to one foot superficial of marle facing, laid Flemish bond.

10 Bricks to one foot superficial of gauged arches.

To reduce Cube feet of brick-work to the standard thickness of 1½ brick, multiply by 8, and divide by 9; the standard thickness of 1½ brick or 13½ inches being nine eighths of a foot.

A stock brick is 8¾ inch. long, 4¼ inch. wide, and 2½ inch. thick; each brick weighs about 4 lbs. 15 oz.

IV.—*Brick and Tile Paving.*

9 Feet superficial, one yard of paving.

72 Paving bricks laid on edge will pave one yard.

52 Stock bricks on edge to one yard.

144 Dutch clinkers laid on edge to one yard.

14 Ten inch tiles will pave one yard.

10 Foot tiles will pave one yard.

A paving brick is 9 inch. long, 4½ inch. wide, and 1¾ inch thick; each brick weighs about 3 lbs. 13 oz.

A Dutch clinker is 6¼ inch. long, 3 inch. wide, and 1½ inch thick; each clinker weighs 1½ lb.

A foot paving tile is 11½ inches square, and 1½ inch thick; each paving tile weighs about 12 lbs. 4 oz.

A ten inch paving tile is 9½ inches square, and 1 inch thick; each paving tile weighs about 8 lbs. 9 oz.

V.—*Tiling.*

100 Feet superficial to one square of tiling, &c.

768 Plain tiles to one square of tiling laid to a 6 inch gauge.

655 Plain tiles to one square of tiling laid to a 7 inch gauge.

576 Plain tiles to one square of tiling laid to an 8 inch gauge.

180 Pan tiles to one square of tiling laid to a 10 inch gauge, with 1½ inch side laps.

A plain tile is 10½ inches long, 6¼ inches wide, and ½ an inch thick; each tile weighs about 2 lbs. 5 oz.

A pan tile is 13½ inches long, 9½ inches wide, and ½ an inch thick; each tile weighs about 4 lbs. 11 oz.

A square of plain tiling, say 700 tiles to a square, will weigh 14½ cwt.

A square of pan tiling, 180 to a square, will weigh 7½ cwt.

VI.—*Laths.*

100 Plain tile laths, 5 feet long, or 500 feet running, of any length, one bundle.

125 Ditto, 4 feet long, one bundle.

167 Ditto, 3 feet long, one bundle.

1 Bundle of laths to one square of plain tiling.

12 Pan tile laths, 10 feet long, one bundle.

1 Bundle of pan tile laths to one square of pan tiling.

30 Bundles of plain tile laths, one load.

Plain tile laths are 1¼ inch wide, and a quarter of an inch thick.

Pan tile laths 1½ inch wide, and 1 inch thick.

VII.—*Lime.*

25 Striked bushels, or 100 pecks, one hundred of lime.

8 Gallons, or 2218½ cubical inches, one bushel dry measure.

277¼ Cubical inches, one gallon.

46656 Cube inches, one cube yard, or 27 cube feet, containing 21 bushels.

$32\frac{1}{11}$ Feet cube, one hundred of lime.

$1\frac{1}{2}$ Hundred of chalk lime to one rod of brick-work.

1 Hundred of stone lime to one rod of brick-work.

2 Bushels of lime to one square of plain tiling.

VIII.—*Sand.*

18 Heaped bushels, 22 striked bushels, or one yard cube, one single load of sand.

36 Heaped bushels, 44 striked bushels, or two yards cube, one double load of sand.

3 Single loads of sand to one rod of brick-work with chalk lime.

$3\frac{1}{2}$ Single loads of sand to one rod of brick-work with stone lime.

1 bushel of sand to one square of plain tiling.

IX.—*Mortar.*

27 Cube feet, or 22 striked bushels, one load of mortar.

Half a hundred of lime with a proportionable quantity of sand, will make one load of mortar.

1134 Cube inches, or 8 duodecimal inches, one hod of mortar, a hod being 9 inches by 9 inches, and 14 inches long.

2 Hods of mortar to a bushel nearly.

$2218\frac{1}{2}$ Cube inches, one bushel.

1728 Cube inches, one cube foot.

1 Foot three inches cube, one bushel.

4 Hods of mortar will lay 100 bricks.

180 Hods, or 96 bushels of mortar, to one rod of brick-work.

X.—*Roman Cement.*

1 rod of brick-work requires 68 bushels of cement.

1 Cubic yard of brick-work requires 6 bushels of cement.

1 Yard square of 14 inch. walling, $2\frac{1}{4}$ bushels of cement.

1 Yard square of 9 inch. walling, $1\frac{1}{2}$ bushels of cement.

1 Yard square of 4 inch. walling, $\frac{5}{8}$ bushel of cement.

1 Yard square of pointing to brick-work, $\frac{1}{2}$ bushel of cement.

1 Yard square of plain surface in plaistering, $\frac{3}{4}$ bushel of cement.

XI.—*Slates.*

1 Ton of Westmoreland slates will cover 2 squares.

1 Ton of Welch rag will cover $1\frac{1}{2}$ to 2 squares.

1000 Dutchess slates will cover 9 squares.

1000 Countess slates will cover 5 squares.

1000 Ladies slates will cover $3\frac{1}{4}$ squares.

1000 Tavistock slates will cover $2\frac{3}{4}$ sqrs.

A square of Westmoreland, or Welch rag slating, will weigh 10 cwt.

A square of Dutchess, Countess, or Ladies slating, will weigh 6 cwt.

Welch slates, called—	ft.	in.		ft.	in.
Doubles, average	1	1	by	0	6
Ladies	1	3	–	0	8
Countesses	1	8	–	0	10
Dutchesses	2	0	–	1	0
Rags	3	0	–	2	0
Queens	3	0	–	2	0
Imperials	2	6	–	2	0
Patent Slates	2	6	–	2	0

XII.—*Gravel.*

27 Heaped bushels, one load.

A yard cube of solid gravel, containing 18 heaped bushels before digging, will produce 27 heaped bushels when dug.

XIII.—*Night Soil.*

18 Cube feet, one ton.

45 Cube feet, $2\frac{1}{2}$ tons, being the quantity contained in each load, the carts being usually made 6 feet long, 3 feet 3 inches wide, and 2 feet 4 inches deep.

XIV.—*Carpenter.*

100 Feet superficial, one square of boarding, flooring, &c.

50 Cube feet, one load of timber.

40 Cube feet, one ton of oak timber.

120 Deals make one hundred.

1 Hundred (120) 12 feet $2\frac{1}{2}$ inch. deals, 9 inches wide, equal to $4\frac{1}{2}$ loads of timber, each deal containing 1 foot $10\frac{1}{2}$ inch. cube.

1 Hundred (120) 12 feet 3 inch. deals, 9 inches wide, equal to 5 and two-fifth loads of timber, each deal containing 2 feet 3 inches cube.

XV.—*Weight of Roof Covering.*

1 Square pan tiling will weigh $7\frac{1}{2}$ cwt.

1 Square plain tiling will weigh $14\frac{1}{2}$ cwt.

1 Square Dutchess, Countess, or Ladies slating, will weigh 6 cwt.

1 Square Welch rag or Westmoreland slating, will weigh 10 cwt.

1 Square lead covering, 7 lb. to the foot superficial, will weigh $6\frac{1}{4}$ cwt.

1 Square copper covering, 16 ounces to the foot superficial, will weigh 1 cwt.

XVI.—*Weight of Materials.*

	tons.	cwt.
64 Cube feet of fir timber	1	0
39 Cube feet of oak	1	0
60 Cube feet of elm	1	0
45 Cube feet of ash	1	0
35 Deals, 12 feet long, $2\frac{1}{2}$ inch. thick,	1	0
15 Cube feet of Portland	1	0
13 Cube feet of marble	1	0
20 Cube feet of chalk	1	0
55 Feet superficial of Purbeck paving	1	0
70 Feet superficial of Yorkshire do.	1	0
24 Cube feet of sand	1	0

	tons.	cwt.
18 Cube feet of earth - - - -	1	0
17 Cube feet of clay - - - -	1	0
36 Cube feet of water - - - -	1	0
450 Stock bricks - - - -	1	0
1000 Stock bricks - - - -	2	4
1 Rod of brick-work - - - -	13	0
1000 Plain tiles - - - - -	1	1
1000 Pan tiles - - - - -	2	2
100 Foot paving tiles - - - -	0	11
100 Ten inch paving tiles - - -	8	7¾
Bar iron, 1 inch square, weight, *per foot run,* - - - - - - -	*lb.*	3½
Ditto, 2 inches square - -		13¾
Ditto, 3 inches square - - - -		31
Ditto, 3½ inches square - -		42

XVII.—*Specific Gravity and Weight of Materials.*

	ounces.		lbs.	ozs.
1 Cube foot of water -	1000	or	62	8
1 Cube foot of fir -	550	or	34	6
1 Cube foot of elm - -	600	or	37	8
1 Cube foot of beech -	700	or	43	12
1 Cube foot of maple -	755	or	47	3
1 Cube foot of ash -	800	or	50	0
1 Cube foot of oak -	925	or	57	13
1 Cube foot of mahogany	1063	or	66	7
1 Cube foot of sand -	1520	or	95	0
1 Cube foot of chalk -	1793	or	112	1
1 Cube foot of common earth - - - -	1984	or	124	0
1 Cube foot of brick -	2000	or	125	0
1 Cube foot of clay -	2160	or	135	0
1 Cube foot of common stone - - - - -	2500	or	156	4
1 Cube foot of flint -	2570	or	160	10
1 Cube foot of marble -	2705	or	169	1
1 Cube foot of granite -	3500	or	218	12
1 Cube foot of green glass	3600	or	162	8
1 Cube foot of white lead	3160	or	197	8
1 Cube foot of cast iron	7425	or	464	1
1 Cube foot of wrought iron	7645	or	477	13
1 Cube foot of copper -	9000	or	562	8
1 Cube foot of lead -	11325	or	707	13

XVIII.—Sundries.

Linear or Running Measure regards only Length, but has no regard to the Breadth or Thickness.

12 Inches, one foot.
3 Feet, one yard.
5½ Yards, one rod or pole.
1760 yards, one mile.
5280 Feet, one mile.

Superficial or Square Measure regards the Length and Breadth.

144 Square inches, one square foot.
272¼ Square feet, one square rod or pole.
43560 Square feet, or 4840 square yards, or 160 square poles, one square acre.
9 Square feet, one square yard.
100 Square feet, one square of flooring, tiling, slating, &c.

Solid or Cubical Measure regards the Length, Breadth and Thickness.

1728 Cube inches, one cube foot.
46656 Cube inches, one cube yard.
27 Cube feet, one cube yard.
34⅗ Cube inches, one pint dry measure.
277⅕ Cube inches, 8 pints, or one gallon.
554⅗ Cube inches, 2 gallons, or one peck.
2218⅕ Cube inches, 4 pecks, or one bushel.
17745⅗ Cube inches, 8 bushels, or one quarter.
1 Foot, 3 inches cube, one bushel.
10 Feet cube, one quarter of corn, &c.
277¼ cube inches, one gallon.

14971 Cube inches, or 8⅔ cube feet, in one hogshead of beer, containing 54 gallons.

13308 Cube inches, or 7¾ cube feet, in one hogshead of ale, containing 48 gallons.

17467 Cube inches, or 10⅛ cube feet, in one hogshead of wine measure, containing 63 gallons.

9981 Cube inches, or 5⅓ cube feet, a barrel containing 36 gallons.

29943 Cube inches, or 17⅓ cube feet, a butt, containing 108 gallons.

1 Barrel of beer will weigh 367½ lbs., or 3 cwt. 1 qr. 3 lbs.

1 Butt of beer will weigh 1102 lbs., or 9 cwt. 3 qrs. 10 lbs.

1 Cube foot will contain 6 gallons and 1 pint of beer, or water, which will weigh 62½ lbs.

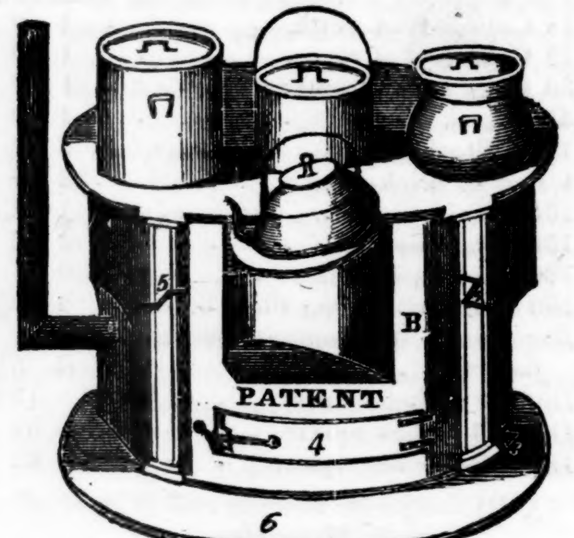
A bushel striked is to a 5 bushel heaped as 4 is to 5.

The least whole numbers that will form a right angled triangle, or make a square, are 3, 4, 5, or any multipliers of them, as 6, 8, 10, or 9, 12, 15, &c.

The breadth of paper for hanging rooms being twenty inches broad, therefore any number of superficial feet divided by five will give the number of yards of paper necessary to paper the room.

XIX.—*A Table showing the Weight per Foot Superficial of Lead, from one sixteenth of an Inch thick to one Inch thick.*

Thickness.	Weight per foot super.
1/16 - - - - -	3¾
1/12 - - - - -	5
1/10 - - - - -	6
1/8 - - - - -	7½
1/6 - - - - -	10
1/5 - - - - -	12
1/4 - - - - -	14¾
1/3 - - - - -	19¾
1/2 - - - - -	29½
3/4 - - - - -	44¼
1 inch - - - -	59



Camp's Patent Double Flue Cooking Stove.

To the Editor of the Mechanics' Magazine:

Dear Sir,—I have lately made what I deem an important improvement in the common cooking stove, and for which I have obtained a patent. The stove is known as H. W. Camp's Patent Double Flue Cooking Stove, and presents by far greater advantages to the economist than any stove of the kind heretofore offered to the patronage of the public.

References—A, front view; B, back view; 1, fire door; 2, gridiron on sunk hearth; 3, damper to flue under oven; 4, oven door; 5, cranks to dampers; 6, lower hearth.

This stove, as you will perceive by a reference to the engravings above, brings the fire immediately in contact with the vessels of various kinds which are used for cooking: the hearth on which the fire is placed being above the oven, and the whole top of the stove left to be occupied with the places for the different cooking utensils, and not in the least interfered with by the pipe of the stove, which is at one end. The draft of the stove divides in the centre when both dampers are up, passing to each end; at one end immediately into the pipe, and at the other end downwards, under the bottom plate of the oven, and, ascending at the opposite end of the stove, uniting with the other draft, and passing out of the pipe, thus imparting heat as well to the bottom and ends as to the top of the oven, or, in other words, completely surrounding the oven with heat by this arrangement of the fire and draft. There are, it will be perceived by the plate, two cranks at figs. 5; these turn, as may be desired, the dampers which close the flues, so that, while baking, the whole draft may be directed under the bottom of the oven by shutting down the damper at the end where the pipe is, and opening the other. By a reference to the engravings it will be seen that the hearth of the fireplace is so arranged as to admit of the coals from the fire being drawn out for the purpose of using a gridiron for broiling; the draft is so strong that the smoke goes into the stove while the broiling is going on. In closing these few remarks, I would observe that no apprehensions need be entertained about the smoke of the fire coming into the room, for with all the lids off not a particle will escape, it all passing off by the pipe.

With respect, yours, &c.

H. W. Camp.

Oswego, N. Y., Nov. 1, 1834.

Mechanism of Hearing.—The ear, properly so called, by its excavations, gathers the sonorous undulations, and directs them towards the auricular canal. In this first passage, the sound is united into a focus; and, for this reason, it augments in intensity; it follows the auricular canal, and soon reaches the membrane of the tympanum, to which it communicates its vibrations; this latter being thin, dry, elastic as the head of a drum, and consequently well calculated to repeat the sonorous waves, transmits them to the internal ear by three several means, namely, the chain formed by the *small bones;* the *walls of the cavity* of the tympanum, which are elastic; finally, and especially, *the air* which fills up this cavity. Then the membranes of the *foramen ovale* and *foramen rotundum,* and of the vestibule, which are dry and vibratory, like that of the tympanum, participate in the oscillations, and transmit them to the *lymph* of *Cotugno* contained in the different passages of the labyrinth. Finally, the humor presses vi-

bratory sonorous waves against the nervous expressions which float in its interior, and the impression which they receive is, lastly, transmitted through the acoustic nerve to the sensorium commune.

The experiments of Mr. Savart are a positive demonstration of the effect of the sonorous waves or undulations on the membrane of the tympanum.

Sound, sometimes, does not follow the course which we have just indicated. For instance, when stopping our ears, we still hear the ticking of a watch placed between our teeth; the sonorous undulations are then communicated by the bony structure of the cranium to the acoustic nerve—solids being, under certain circumstances, excellent conductors of sound.

Such is, in an abridged manner, the physical history of hearing; beyond this, we have no positive knowledge.

But physiologists wish to give more precision, and describe in a more special manner the part that each portion of the ear acts; we shall see, while examining the principal hypotheses, that they are far from having thrown any light on this phenomenon.

Dumas considers the membrane of the tympanum as being formed of concentric curved lines, which have the property of vibrating each in a particular tone; and others have advanced that the difference of tones results from the different degrees of tension of this membrane.

We have had under our care several individuals who were deaf, and in whom this membrane was wanting; but after the true cause of deafness was removed, the patients heard perfectly well every *tone* or spoken language, without having recovered the membrane of their tympanum. So that these facts do away these hypotheses of Dumas and others.

As to the small bones, it has been presumed that they strike on each other, or on the membrane of the tympanum only; hence their names of *hammer* and *anvil*. We conceive that such hypotheses do not deserve to be repeated. Besides the use which we have already assigned to them, it is generally admitted that they modify the degrees of tension of the *membrane of the tympanum*, and of the membrane of the *foramen ovale*.

Their anatomical structure, their articulations, their muscles intended to move them, are the best proofs of the movements they must perform, and of their being thus used.

Some physiologists have supposed that the *Eustachian tube* permitted sonorous undulations to pass, instead of being singly a passage for the air to enter into the cavity of the tympanum. This may be immediately disproved by placing a watch in the mouth so as not to touch any solid part, in which case the tick of the watch is not heard; but if the watch be permitted to touch the teeth, then it will be heard, and that through the continuous connection of solid bodies which are conductors of sounds.

What, you may ask, is the use, then, of these bones, and of the membrane of the tympanum? Why, you may also ask with propriety, should *nature* bestow upon our species so very delicate and complicated an apparatus, if we may hear just as well without it? We understand the import of such questions, and cannot deny their force; but we shall remain satisfied with the facts we have observed, and shall not try to explain what we conceive is, till now, above the comprehension of every human being.

The case of ——— ——, who had lost both the membranes of the tympanum, and all the small bones, as well as the case of Mr. ———, who also has lost the same parts, and both these individuals still hearing perfectly the human voice, or any other sound, are, to us, obvious proofs that the proper and indispensable part of the organ of hearing is the labyrinth and acoustic or auditory nerve.

This we observe to exist in some animals where there is no auricular or introductory tympanum, no bones of the cavity of the ear; but the undulations of the air are received at once on a membrane which communicates them to the labyrinth, and thus to the nervous expansions of the auditory nerve.

If, however, in man, or those animals which have a tympanum, the last bone of the series—the stirrup—is lost, the membrane covering the oval hole will be generally destroyed also; and as the fluid contained in the inner ear (*the lymph of Cotugno*) will, in consequence, escape, deafness will ensue, from the medium being lost, by which the immediate organ of hearing becomes affected. The same thing happens whenever the membrane of the round hole is destroyed.

The immediate function of the organ of hearing is, as we have already stated, to give us the sensation of sounds; but its mediate functions being more closely connected with, and serving more intimately, the mind, than those of taste or smell, has caused this organ to be placed on a par with touch and sight.

We may, in fact, by means of hearing, ascertain the nature of bodies, the situation they occupy, the distance at which they are placed, the direction in which they move,

&c. This sense, moreover, assists the intellectual faculties: those of *music* and *language*, for instance, without which they can no longer be exercised.

Metaphysicians, struck with its great utility, in the exercise of these faculties, have exclusively ascribed them to this organ.

There is a great deal of difference between that power of perception which constitutes hearing, and that which is connected with the appreciation of musical sounds; for if the faculty of combining sounds according to harmonic relations, and so as to constitute *music*, be the mere product of the sense of hearing, then this faculty ought to be possessed by all animals, and by every man, in the same ratio with the perfection of the structure of their ears. This, however, is not so. Many animals hear better than man, and, nevertheless, none possess the faculty of music to the same extent. No relation is observable, in animals, between the power and character of their music and the perfection of their hearing: for instance, the birds which do not sing have as nice an ear, with respect to mere hearing, and some even more, than the singing birds.

Again, among the singing birds, often the male alone has this instinct of pouring forth their strain. Many of these singing birds sing only at certain periodical seasons. Shall we say, in this instance, that they are all at once excited at this period, or periodically endowed with this faculty, and afterwards fall again into the same apathy, although the ear of these animals remain the same at all times?

The ear of all birds is nearly constructed on the same plan. They have no external ear or auricle; the cavity of the tympanum contains only *one bone* instead of *four*, as in man, and the cochlea is a cone slightly curved. Notwithstanding this very great similarity of structure, each one of them has preserved, ever since the creation, its peculiar note, or series of notes, and has acquired no others. There is, however, an exception in the mocking bird.

The elephant, which has a nicer apprehension of sounds than man, (as we shall prove it by an anecdote presently,) has no faculty whatsoever for music. The parrot, it is well known, can be taught to speak any language, and, of course, must have a very nice, discriminating ear; he, however, never sings, and the tones of his voice are far from being musical.

Finally, we do not see that, in man, musical talent or correct elocution is in the same ratio with the nicety of hearing. Men who have the most delicate hearing often cannot sing at all—Mr. Burke and Dr. Johnson are instances of it. Idiots, who hear very well, cannot learn how to sing the simplest melody, or utter spoken languages intelligibly. From these facts we are inclined to conclude that the faculty of music does not depend upon the organ of hearing solely, but is a superior intellectual endowment, for the acquisition of which the ear is merely a secondary instrument.

We might, with the same propriety, ascribe to the eye exclusively the faculty that painters have of executing historical paintings, or in any other style, as to attribute to the ear the power of music. Then every man would be a painter; but we know that some cannot even conceive what lines represent, intended to delineate an object.

The same is the case with spoken languages. If we suppose that animals have none, why then have they a hearing at all—to which metaphysicians ascribe also the faculty of language? Why, with the possession of this organ, they do not form a language like that of man, or something like it?

If, on the contrary, we suppose that they have a language: why, then, with an organ constructed always nearly on the same plan, are languages in animals so different—for each one has it peculiar articulations of sounds? It may be asked, how is it that man, with the same organ of hearing, has, in different countries, various languages and articulations? This is true, when he wishes to express abstract conditional ideas; but all men, however, use the same *tones* to express their passions or sentiments, which is in fact the natural language of man, as singing is the natural language of birds. Why has each of them its peculiar language? Finally, do we find that in man the faculty of spoken language is in the same ratio of the nicety of his hearing? Do we find that poets and orators have the best hearing? Idiots, with an exquisite nicety in hearing, can never learn how to speak or sing.

To us it is also certain that the faculty of spoken language is a superior intellectual faculty, for which hearing is, there is no doubt, an indispensable but secondary instrument, and destined solely to convey to the brain sonorous sensations, to which the latter alone connects ideas. Languages also follow the same progress as that of civilization, and of the ideas diffused and in circulation in a nation. Books are merely the depository of the march of mind. Oral language, and languages generally, like nations and empires, have their period of rudeness, of improvement, amelioration, and have also

the seeds of decay and degradation, keeping pace precisely with the improvement and decline of morals or sciences; for, being the result of society, they are *man* himself, manifested in his moral capacity by these external sounds or signs. It is the index of his character and calibre of his mind; his speech or style must unquestionably unfold his cast of mind and manners, and paint the high or low origin of his sentiments. A man's works are the mirror of his soul. The more a man or nation extends his relations, the richer his language becomes; the more, also, the individuals speaking it will become polished and learned. The same is the case with respect to a deaf and dumb subject who has recovered his hearing: every new subject with which he becomes acquainted, he naturally acquires a new dictionary of words and phrases in proportion to the acquisition of the number of his new ideas. A stationary language like the Chinese informs us, as clearly and as evidently as if we were reading the pages of its history, that its government, manners, religion, laws, sciences, and arts, are also perfectly stationary. See, on the contrary, the revolution produced in the French language by the *political* revolution of '92. Then, we may conclude, that languages are so truly the creation of the mind, that in every nation, as in individuals, they are in strict relation with the number and character of their ideas and opinions, or, in other words, they are the true index of their mind; that it is correct to say, that the amount of a man's knowledge is equal to his language; and it is equally correct to say, with Charles the Fifth, that an individual is as many times a man as he speaks different languages. Therefore, a deaf and dumb is scarcely a man. Oral language without society cannot exist in man; for all individuals who have been found wild in the forest, although their parents spoke some one known oral language, still they imitated simply the sounds of the animals which they frequented and daily heard. Monkeys, which resemble man in many respects, are not endowed by our Creator with the faculty of speech; and this faculty, more than any other perhaps, distinguishes man from every other animal. Thus, man alone speaks; for as to the sounds uttered by parrots, it cannot be said that they speak a language, since we know that they attach no ideas to the sounds to which they give utterance; and this, in our minds, is another proof that, to possess the mere *oral organ*, as in the case of the parrot, or the few words that the deaf and dumb may utter, is not sufficient to say that the individual can *speak* and *think* in that language. Idiots, although they have the *oral organs* perfect, cannot speak, because they want the moving power—the mind. Also, that whenever a nation has acquired many ideas, its language becomes rich in proportion, and in consequence of it. Thus, Italy, among modern nations, who, when other nations of Europe had scarcely a language, had a most beautiful and perfect one—rich in every mode of expression; she had also, so far back, distinguished poets, and legislators, statesmen, and philosophers; celebrated historians; painters, sculptors, architects, and musicians; great captains; mariners, the conqueror of a new world; discoverer of the mariner's compass; merchants, who exchanged the productions of the west with those of the eastern hemisphere; who have first established banks, bills of exchange, and post-offices; who first established a militia system, tactics of warfare, fortifications, and internal improvements. And, to use the language of the poet,

> "Birthplace of heroes, sanctuary of saints,
> Where earthly first, then heavenly glory made
> Her home; thou all which fondest fancy paints,
> And finds her prior vision but portray'd
> In feeble colors, ———————."

But, to return. If an individual have a strong mind, thinks profoundly, and feels deeply, his language partakes of the grandeur of his thoughts, and he speaks warmly, cogently, and energetically. If, on the contrary, he wants ideas and affections, he is silent, or if he speaks at all, he is insipid, flat, and his language is devoid of any coloring.

Although the hearing of man has a great degree of perfection, still this sense, in many animals, seems to be even richer in its discrimination, if we may be allowed especially to judge, in certain cases, by the size of the nerve, and the greater developement of the whole organ in advance.

The ears of animals offer a great variety of structure in their details. Indeed, we observe this structure to be from the existence of a mere sac, having apparently no nervous pulp on it, up to the complicated apparatus such as we have demonstrated in man.

There is every reason to suppose, that, as some small animals have microscopic eyes, and possess a power of vision far beyond what is necessary to us, or what we are capable of exercising, there is also, in many, a minute and accurate appreciation of sounds, of which we can form no conception, not until we shall find microscopes and telescopes for our ears.

Our knowledge of the comparative acuteness in the auditory faculty of animals is not very extensive. The elephant, however,

is said to be endowed with a remarkably acute sense of hearing. Its auditory organs, it is true, are larger than in other animals, or man himself; and Sir Everard Home, while dissecting its ear, discovered that the membrane of the tympanum was muscular. Mr. Corse, who saw much of the habits of the elephant in India, states that a tame elephant, which was never reconciled to have a horse moving behind him, although he expressed no uneasiness if the horse was within his view, either before or on one side, could distinguish the sound of a horse's foot at a distance, some time before any person in company heard it. This was made manifest by his pricking up his ears, quickening his pace, and turning his head from side to side.

He also mentions a tame female elephant, which had a young one, that was occasionally sent out with other elephants without the young one being allowed to follow. She was not in the habit of pining after it, unless she heard its voice; but frequently on the road home, when no one could distinguish any sound whatever, she pricked up her ears and made a noise expressive of having heard its call. This having occurred frequently, attracted Mr. Corse's notice, and made him, at the time the female elephant used these expressions, stop the party, and desire the gentlemen to listen; but they were unable to hear any thing till they had approached nearer to the place where the young one was kept.

We shall in this place remark, that we are able to determine the power of hearing by the distance at which a given sound, used as a standard, may be heard; this refers merely to the intensity of the sound, but we have no means of determining as to the tone and timbre, no more than we can ascertain if we all see the same color, possessing the same hue. We have, in fact, no means of ascertaining if all animals perceive, if not the same *tone*, at least the same *timbre*. It appears from some observations of Dr. Wollaston, that some persons are insensible to various sharp sounds, as the chirp of the house sparrow, and house cricket, the squeak of a bat, and the noise of small insects, without having any other defect in the organ.

We have had under our care two young ladies, who could hear, on the contrary, when at a distance, the voice of a bird, while at the same distance they could not hear the noise of a cart, or hear thunder itself.

If a different organization of the gustatory and olfactory nerves have made persons perceive different odors and tastes in the same substance, or smell one odor and not be able to smell another, why should not a different organization of the acoustic nerve make us perceive also different *timbres* in the same sonorous body, or hear one kind of sound and not others? But this is impossible either to prove or to deny. These remarks especially apply to the differences we find in the sense of hearing of various men.

These differences arise also from, 1st, the intimate structure of the acoustic nerve; 2d, the more or less perfect structure and disposition of the parts in advance of the nerve; and 3d, to the hygeinic precautions necessary to keep the organ in a fit state for the exercise of its functions.

Hearing is one of the senses which most enlarge our intelligence; and like all the other senses, it may acquire power and perfection by practice, and we may exercise it passively or actively, that is to say, we may *hear* or *listen to*.—[From Dr. Togno's Treatise on the Laws of Acoustics.]

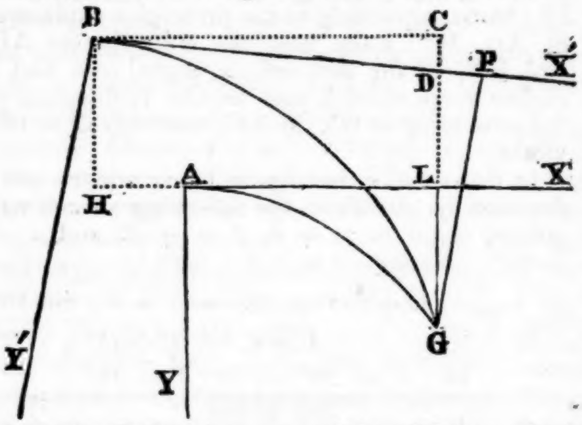
On the Location of Railroad Curvatures; being an Investigation of all the Principal Formulas which are required for Field Operations, in laying Curves and Tangent Lines, to pass through Given Points. By J. S. Van De Graaff. [From the American Railroad Journal.]

(Continued from page 304.)

22. Let two curves be under consideration having different origins, and tangent lines; and let one of those curves be given, and a point designated therein, through which the other curve is required to pass. Take a system of rectangular co-ordinate axes, corresponding with the given origin, and tangent line, of the given curve, and let the co-ordinates of that point which is designated for the required curve to meet be x, y; the value of these co-ordinates being computed by means of (VII.) if the given curve be already laid in the field, but determined by means of a system of rectangular lines when that curve has not been actually laid. Let the co-ordinates of the *new origin*, taken with reference to the axes of x, y, and determined either by computation or by means of a system of rectangular lines, be denoted by α β; α *being supposed to coincide with the axis of* x. And lastly, take z to denote the given inclination of the tangents at the origins of the two curves. From those data it is then proposed to find the modulus of curvature of the required curve, such that it may pass through the designated point.

Take a new system of rectangular co-ordinate axes, corresponding with the origin and tangent line of the required curve; and agreeably to these, let x', y', represent the new co-ordinates of the point designated in the given curve. It is then very obvious that the required modulus of curvature will be immediately derived from (XI.), when the new co-ordinates x', y', become known. The value of those co-ordinates must therefore be sought

agreeably to the known methods of analytical geometry, for the transformation of co-ordinates. Let A be the origin, and G the designated point, in the given curve AG; and take



the point B for the new origin of the required curve BG, and AX, AY, and BX', BY', for the two given systems of rectangular co-ordinate axes; the two tangent lines coinciding with AX and BX' respectively. Let such lines be drawn as appear obvious upon the figure, and the following values will then obtain: $x = AL$, $y = LG$, $\propto = AH$, $\beta = HB$, $x' = BP$, $y' = PG$, and $z = \angle CBD = \angle LGP$.

By plane trigonometry $CD = \overline{x + \propto} \cdot$ Tan. z; and consequently $DG = y + \beta - \overline{x + \propto} \cdot$ Tan. z; but again by plane trigonometry, $PG = DG \cdot$ Cos. z. Hence, $PG = \overline{y + \beta} \cdot$ Cos. $z - \overline{x + \propto} \cdot$ Sin. z. In like manner it will be found that $BP = \overline{y + \beta} \cdot$ Sin. $z + \overline{x + \propto} \cdot$ Cos. z. The values of the new co-ordinates will therefore be expressed as follows:

$$x' = \overline{y + \beta} \cdot \text{Sin. } z + \overline{x + \propto} \cdot \text{Cos. } z$$

$$y' = \overline{y + \beta} \cdot \text{Cos. } z - \overline{x + \propto} \cdot \text{Sin. } z. \quad \text{(XXI.)}$$

Such are the formulas to be used in the field, when a new system of co-ordinates must be computed; they are the well known expressions given by most authors for the transformation of rectangular co-ordinates, and they only here stand transposed in such a manner as will best suit the engineer's purpose in the present inquiry.

It may be observed, that the value of the angle z need never be obtained by a measurement with the instrument; for it may always be easily computed from the manner in which the two origins, at A and B, have been obtained.

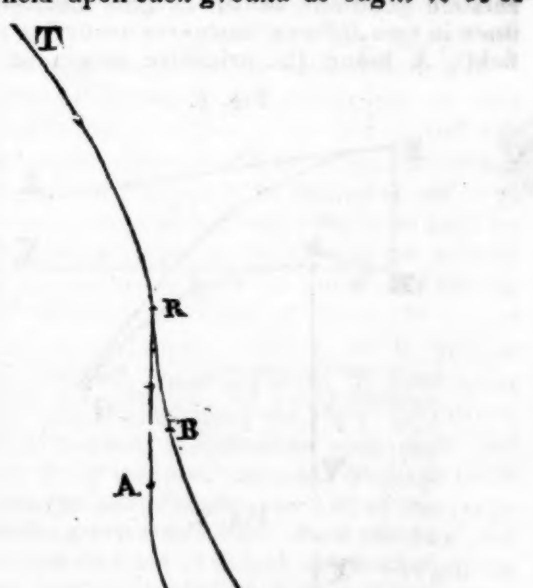
The value of the new co-ordinates having been found, the required modulus of curvature may be easily computed by means of (XI.) as before remarked. But a direct formula will be more convenient for use; and in order to obtain such a formula, let each of (XXI.) be squared, and the result will give $x'^2 + y'^2 = \overline{y + \beta}|^2 + \overline{x + \propto}|^2$. Hence denoting the required modulus of curvature by T', the following formula will be immediately derived from (XI.)

$$\text{Sin. T}' = \frac{\overline{y + \beta} \cdot \text{Cos. } z - \overline{x + \propto}\ \text{Sin. } z}{\overline{y + \beta}|^2 + \overline{x + \propto}|^2}. \quad \text{(XXII.)}$$

The theorem thus obtained, expressing the value of T', has a very good form for numerical computations, and when skilfully applied, it will frequently save much labor in the field, which would be otherwise required when *certain alterations* are proposed in a line *once computed, or accurately traced.* And although the co-ordinates $\propto$, β, and the angle z, which expresses the inclination of the axis of x, and of x', to each other, will change their *signs* under different circumstances in the field, yet, to those who are familiar with the use of algebraic formulas, this cannot be a source of any embarrassment. For it has only to be observed that the hypothesis here assumed is, that $\propto$ is accounted *positive* when its direction is immediately *opposite* to the direction of x; and β is, in like manner, accounted *positive* when its direction is immediately *opposite* to the direction of y. And either $\propto$ or β must, in consequence, have its sign *reversed* in (XXI.) or (XXII.), when the circumstances in the field are such as to give either of them the same direction with its respective co-ordinate axis.

The angle z is to be accounted negative, or which is the same thing, the quantity Sin. z must have its sign *reversed*,* in the two following cases: I. When β is positive, and the two tangents diverge *in advance*. II. When β is negative, and the two tangents converge *in advance*. In all other cases the formulas (XXI.) and (XXII.) will retain their present forms, as far as the angle z is concerned.

In order to show *one* case in which an application of (XXII.) will be extremely convenient in practice, let TRS be a curve already laid in the field upon *such ground as ought to be se-*



* *Note.*—Agreeably to the principles of trigonometry, when an arc becomes *negative*, the Sine becomes *negative* also; but the Cosine does not change its sign.

lected, and let SA be a *short* tangent intervening between the given curve TRS, and a certain reversed curve AG, necessary to pass a designated point G. Having traced a system of rectangular lines from the given origin A, and terminating in the designated point G, let the modulus of curvature be computed by means of (XI.) which would trace the curve AG, and let the direction of that curve, at the point G, be examined agreeably to the method explained in Article 16. Now, supposing this curvature is found more abrupt than is thought to be judicious, the only method of alteration will be to take the curve TRS off into a tangent a little sooner, as for instance at the station R, and then a new origin will be obtained at B, in the new tangent RB, for the required curve BG, which is the very case under consideration in the present article. The inclination of the two tangents RB and SA, will be known at once from (IV.); and the co-ordinates of the new origin B may be easily computed by methods to be hereafter explained. By repeating a calculation from (XXII.) for several points in the given curve TRS, it will be easy to select a proper point R, at which to terminate the given curve TR, in order to lay a short tangent RB in such a position as to meet the necessary conditions imposed by the reversed curve BG. Other cases will be hereafter mentioned, in which an application of (XXII.) will be required; but, in the first place, the following examples are here given, amply to illustrate the *various mutations of that formula, under the different circumstances occurring in practice.*

Example 1. Let figures 1 and 2 exhibit the relative positions of the origins and tangent lines in two *different instances* occurring in the field; A being the primitive origin in both figures. Suppose a system of rectangular lines to be traced from the origin A, and terminating in the designated point G, and let the resulting equations give, $x = 17$ chains, $y = 12$ chains, agreeably to the principles explained in Art. 16. Take also the co-ordinates AH and HB, of the *new origin*, equal to 3 and 2 chains respectively, and let the inclination of the new tangent BX′ be 10°, *converging* in advance.

Fig. 1.

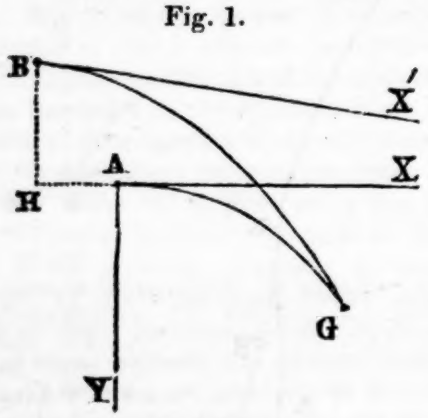
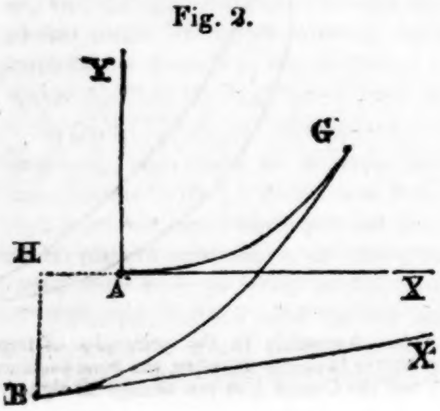


Fig. 2.



In this case, either figure being under consideration in the field, the following values will obtain, viz.: $\alpha = +3$, $\beta = +2$, and $z = +10°$. Hence,

$$\text{Sin. T}' = \frac{\overline{12+2}\cdot\text{Cos. }10° - \overline{17+3}\cdot\text{Sin }10°}{\overline{12+2}|^2 + \overline{17+3}|^2}$$

$$= \frac{14\cdot\text{Cos. }10° - 20\cdot\text{Sin. }10°}{196 + 400} = \frac{14 \times \cdot 98481 - 20 \times \cdot 17365}{596} = \frac{13{\cdot}787734 - 3{\cdot}47300}{596} = \frac{10{\cdot}31434}{596}$$

$= \cdot 01731$; or, $\text{T}' = 0°\ 59\tfrac{1}{2}'$ = modulus of curvature necessary to trace a curve from the *new origin* B to the designated point G.

Example 2. Let the relative positions of the *origins* in two other instances be the same as in figures example 1; and suppose the two tangents to *diverge* in advance.

Here, retaining the same quantities given in the first example, the signs which appertain equally to fig. 1 and fig. 2 are the following, viz.: $\alpha = +3$, $\beta = +2$, and $z = -10°$. And, therefore, in this case,

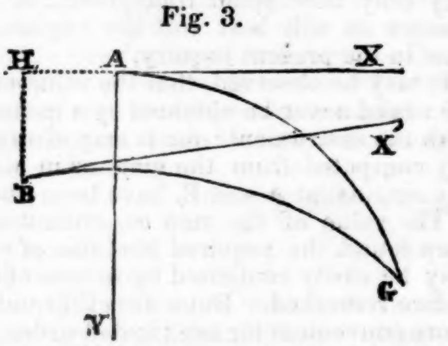
$$\text{Sin. T}' = \frac{\overline{12+2}\cdot\text{Cos. }10° + \overline{17+3}\cdot\text{Sin. }10°}{\overline{12+2}|^2 + \overline{17+3}|^2}$$

$$= \frac{13{\cdot}78734 + 3{\cdot}47300}{596} = \frac{17{\cdot}26034}{596} = \cdot 02896;$$

or, $\text{T}' = 1°\ 39\tfrac{1}{2}'$ = modulus of curvature required.

Example 3. Let the relative positions of the origins and tangent lines be such as is indicated by figures 3 and 4, the primitive origin being

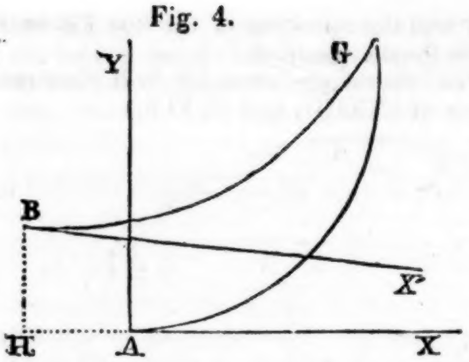
Fig. 3.



represented at A, as before, and the tangents AX, BX′, *converging* in advance. It is evident that the same signs will appertain to both of the figures 3 and 4; that is, $\alpha = +3$, $B = -2$, and $z = -10°$. And therefore in this case,

$$\text{Sin. T}' = \frac{\overline{12-2}\cdot\text{Cos. }10° + \overline{17+3}\cdot\text{Sin. }10°}{\overline{12-2}|^2 + \overline{17+3}|^2} =$$

Fig. 4.



$$\frac{10\times\cdot98481+20\times\cdot17365}{100+400}=\frac{9\cdot84810+3\cdot47300}{500}=$$

$\frac{13\cdot32110}{500}=\cdot02664$; or, $T'=1°\ 31\tfrac{3}{4}'$ = modulus of curvature, which would trace either of the curves, in figure 3 or figure 4, from the *new origin* B to the designated point G.

Example 4. Suppose the relative position of the *new origin* to be such as is represented by figure 3, or figure 4; and let the two tangents AX and BX' *diverge* in advance.

Taking the signs which appertain to this case, the following values will obtain: $\propto = +3$, $B = -2$, and $z = +10°$; and consequently

$$\text{Sin. } T' = \frac{\overline{12-2}\cdot\text{Cos. }10° - \overline{17+3}\cdot\text{Sin.}10°}{\overline{12-2}|^2+\overline{17+3}|^2}=$$

$\frac{9\cdot84810-3\cdot47300}{500}=\frac{6\cdot37510}{500}=\cdot01275$; or, $T' = 0°\ 43\tfrac{3}{4}'$ = new modulus of curvature which would be required in either of the figures 3 or 4, upon the supposition that the tangents AX and BX' *diverge* in advance.

Example 5. Let figures 5 and 6 show the

Fig. 5.

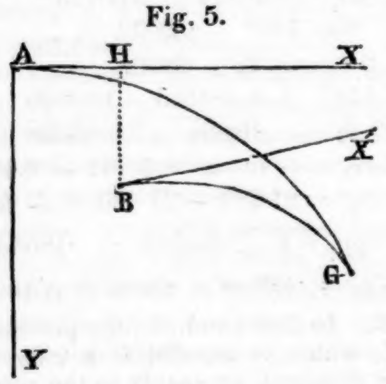
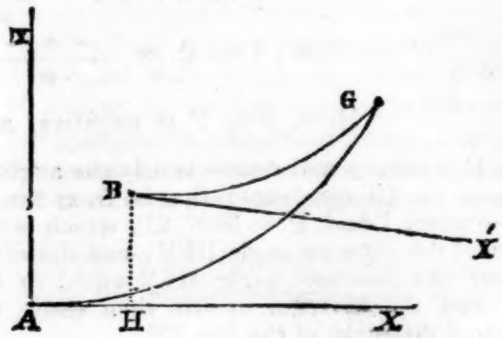


Fig. 6.



relative positions of the origins and tangent lines, as occurring in two different instances; the tangents being represented *converging* in advance.

Here the following values will obviously obtain with reference to either of the figures 5 or 6; that is, $\propto = -3$, $B = -2$, and $z = -10°$. Therefore,

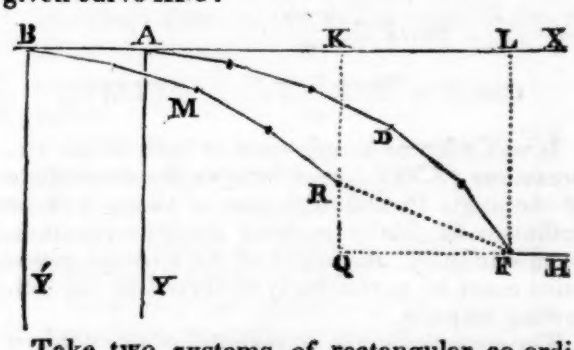
$$\text{Sin. } T' = \frac{\overline{12-2}\cdot\text{Cos. }10° + \overline{17-3}\cdot\text{Sin. }10°}{\overline{12-2}|^2+\overline{17-3}|^2}$$

$$= \frac{9\cdot84810+2\cdot43110}{296}=\frac{12\cdot27920}{296}=\cdot04148;$$

or, $T' = 2°\ 22\tfrac{3}{4}'$ = required modulus of curvature.

The preceding examples do not exhibit all the mutations which will sometimes occur in (XXII) —but are sufficient to explain the principle. The importance of that formula in the field rendered such explanations necessary, in order that those persons who may not be already familiar with that elementary principle of analytical geometry, may nevertheless be enabled to compute without perplexity or liability to error.

23. Suppose ADF to represent a given curve, and BMR another proposed curve laid upon the same tangent line AX, and let $\propto$ denote the given distance AB, between their origins. Take T and T' to represent the given moduli of curvatures, and *n*, and *m*, the given number of chains contained in each curve respectively. It is required to determine the distance FR, between the extreme stations of those two curves; and it is also proposed to show a method by which the instrument may be directed into the line FR, from the extremity of the given curve ADF.



Take two systems of rectangular co-ordinate axes, AX, AY, and BX, BY', corresponding with the common tangent line AX, and whose origins coincide respectively with the origins A and B of the two curves. Taking x, y, to denote the co-ordinates AL, LF, of the extremity of the given curve ADF, their values will be either known from (VII.), or determined in the field by means of a system of rectangular lines. Let x', y', be the co-ordinates, BK, KR, of the extremity of the proposed curve BMR, as estimated agreeably to the proper axes BX, BY'. The differences, KL, RQ, of co-ordinates, will then be expressed by $x+\propto-x'$, and $y-y'$, respectively. Hence, taking w to denote the distance sought, the common principle of analytical geometry gives the following formula:

$$w = \left\{\overline{x+\propto-x'}|^2 + \overline{y-y'}|^2\cdot\right\}^{\frac{1}{2}} \quad \text{(XXIII.)}$$

And thus the distance w becomes known; for the values of the co-ordinates x', y', will be expressed as follows:

$$x' = \frac{\text{Sin. } 2m\text{T}'}{2 \text{ Sin. T}'}$$

$$y' = \frac{1 - \text{Cos. } 2m\text{T}'}{2 \text{ Sin. T}'}.$$

Now, in order to determine a method of directing the instrument into the line FR, when placed at the given station F, let FH be a line whose direction is parallel to the axis of x, and whose position is in *advance* of the station F, with reference to the origin A, upon the axis AX. The instrument may then be directed into the line FH, either by means of (IV.), or by the principles contained in Art. 16, agreeably to the circumstances of the case. Take, therefore, the letter P, to denote the angle of position HFR; and when its value has been computed, by a method which will be presently shown, deflect the angle HFR = P, and the instrument will indicate the required direction FR. And thus the position of the station at R will be seen at once, without actually tracing the proposed curve BMR.

The value of the angle P is now to be investigated. By plane trig. Rad.: Sin. QFR : : FR : RQ; and, also, Rad. : Cos. QFR : : FR : FQ. That is, Sin. QFR $= \frac{y - y'}{w}$, and Cos. QFR $= \frac{x + \propto - x'}{w}$. But, agreeably to the principles of trigonometry, Sin. P = Sin. QFR, and Cos. P = — Cos. QFR. Hence the following formulas are the obvious result:

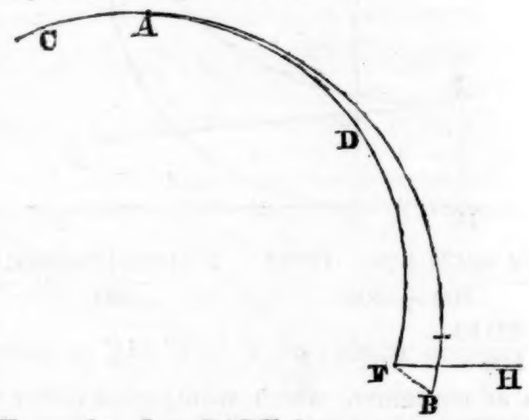
$$\text{Sin. P} = \frac{y - y'}{w};$$

$$\text{Cos. P} = \frac{x' - x - \propto}{w}. \qquad \text{(XXIV.)}$$

It will require a reference to both of the expressions (XXIV.), to determine the magnitude of the angle P, although one of them will be sufficient in finally making the computation. In this inquiry, the *signs* of the various quantities must be particularly observed in the following manner.

The quantity $\propto$ is considered positive when the given origin A is in *advance* of the proposed origin B; and consequently, *in a contrary case*, the quantity $\propto$ must have its sign *reversed* in (XXIII.) and (XXIV.). The angle P is supposed to be measured from the station F, and from the line FH, in a direction increasing from *right to left*, with reference to the line FH, through all four of the quadrants. By observing this principle, the position of the line FH, under all circumstances, will be immediately known from the *signs* of the quantities Sin. P and Cos. P. Thus, when Sin. P and Cos. P are both positive, the line FR will be situated in the first quadrant; when Sin. P is positive, and Cos. P negative, then is the line FR posited in the second quadrant; when Sin. P and Cos. P are both negative, then will the line FR fall in the third quadrant; and lastly, when Sin. P is negative, and Cos. P positive, then will the situation of the line FR be found in the fourth quadrant.

The following example will illustrate the utility of (XXIII.) and (XXIV.)



Example. Let CADF be a curve already traced from a modulus of curvature of 2° 30′, and let A be a station in that curve 30 chains from the extreme station at F. Supposing a change of curvature to be made at A, such as to trace the curve AR, for a distance of 30 chains, from a modulus of curvature of 2° 28′, it is proposed to know how far those two curves would be separated from each other at their extremities; and it is also required to designate a line immediately from the extremity of the given curve, as already laid, to the point where the proposed curve would terminate.

In this case, then, $\propto = o$, $n = m = 30$, T = 2° 30′, and T′ = 2° 28′. Hence, $2n$T = 150°, $2m$T′ = 148°; and therefore, by (VII.),

$$x = \frac{\text{Sin. } 150°}{2 \text{ Sin. } 2° 30'} = \frac{\cdot 50000}{\cdot 08724} = 5 \cdot 731; \; y = \frac{1 - \text{Cos. } 150°}{2 \text{ Sin. } 2° 30'} = \frac{1 + \cdot 86603}{\cdot 08724} = \frac{1 \cdot 86603}{\cdot 08723} = 21 \cdot 389;$$

$$x' = \frac{\text{Sin. } 148°}{2 \text{ Sin. } 2° 28'} = \frac{\cdot 52992}{\cdot 08608} = 6 \cdot 156; \; y' = \frac{1 - \text{Cos. } 148°}{2 \text{ Sin. } 2° 28'} = \frac{1 + \cdot 84805}{\cdot 08608} = \frac{1 \cdot 84805}{\cdot 08608} = 21 \cdot 469.$$

Wherefore, $x + \propto - x' = 5 \cdot 731 - 6 \cdot 156 = - \cdot 425$; $y - y' = 21 \cdot 389 - 21 \cdot 469 = - \cdot 080$; and $w = \overline{\overline{- \cdot 425}|^2 + \overline{- \cdot 080}|^2}|^{\frac{1}{2}} = \overline{\cdot 1806 + \cdot 0064}|^{\frac{1}{2}} = \overline{\cdot 1870}|^{\frac{1}{2}} = \cdot 433$ of a chain = required distance FR. In this example, the position of the line FH, which is parallel to a tangent at A, must be obtained agreeably to the method explained in Art. 11; and then, Sin. P $= \frac{y - y'}{w} = \frac{- \cdot 080}{\cdot 433} = - \cdot 1848$; Cos. P. $= \frac{x' - x - \propto}{w} = \frac{+ \cdot 425}{w}$. Here, Sin. P is negative, and Cos. P positive; and consequently the angle P falls in the 4th quadrant; that is, from Sin. P = — ·1848, I find, P = 349° 21′, which is the value of the *exterior* angle HFR; and therefore deflect the *interior* angle HFR equal to 10° 39′, and the instrument will then show the required direction of the line FR.